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CORRESPONDENCE AND NOTES

The evolution of the early Carboniferous Limestone province in southwest Britain

SIRS – Research into limestones has recently turned from detailed, small-scale facies analysis to looking at the evolution of carbonate sequences on a broad scale. Carbonate sediments today form in three main geomorphic settings: ramps, shelves and platforms (Ginsburg & James, 1974; Read, 1982; Tucker, 1985). The controls on the development of thick limestone sequences in each of these settings, such as tectonics-subsidence, eustatic sea-level changes and intrinsic sedimentary processes, are becoming better understood (Kendall & Schlager, 1981; Schlager, 1981). Models have been developed which enable analogous geomorphic provinces to be recognized in the geological record (Read, 1982, 1985), and these large-scale models can be used to give new perspectives to many limestone successions and can reveal complex, evolutionary developmental stages hitherto unsuspected.

One of the largest carbonate sequences in Britain is represented by the Lower Carboniferous limestones of south Wales and the Bristol–Mendip area (Fig. 1). The sequences consists of a southward-thickening wedge of limestones and dolomites, over 1500 m thick in southerly outcrops. The limestones overlie the fluvial Old Red Sandstone (Devonian) and are overlain by the deltaic-paralic Upper Carboniferous. The southern margin with the Cornubian Basin to the south is problematic because the transition is not exposed and major tectonic displacement has also occurred (Johnson, 1984).

The limestone sequence has previously been interpreted as having been deposited on a carbonate shelf (Ramsbottom, 1970). Recent work has revealed a more complex history suggesting that the province passed through three stages before finally achieving a typical shelf configuration. These stages can be recognized by interpreting and comparing the broad facies sequences developed sequentially during the early Carboniferous. This is now possible because a number of recent studies have detailed the facies types in the sequence enabling this integration into an overall model.

Stage I. During earliest Dinantian times (Hastarian or early Courceyan) a major transgression, probably eustatic (Johnson, 1982), flooded the Old Red Sandstone alluvial plains of southwest Britain. The depositional unit represented by this stage is the Lower Limestone Shale Group (Cefn Bryn Shale Group of South Wales), which has been described in detail by Burchette (1986, and T. P. Burchette, unpub. Ph.D. thesis, Univ. Wales, 1977). Much of the unit consists of mudstones and shales interpreted as offshore muddy facies. There is evidence in the form of carbonate barrier facies of up to three minor regressive (progradational) phases during the deposition of the mudrocks but each was short-lived and the unit culminates in very extensive mudrock deposition representing the maximum extent of the Carboniferous transgression (George, 1972).

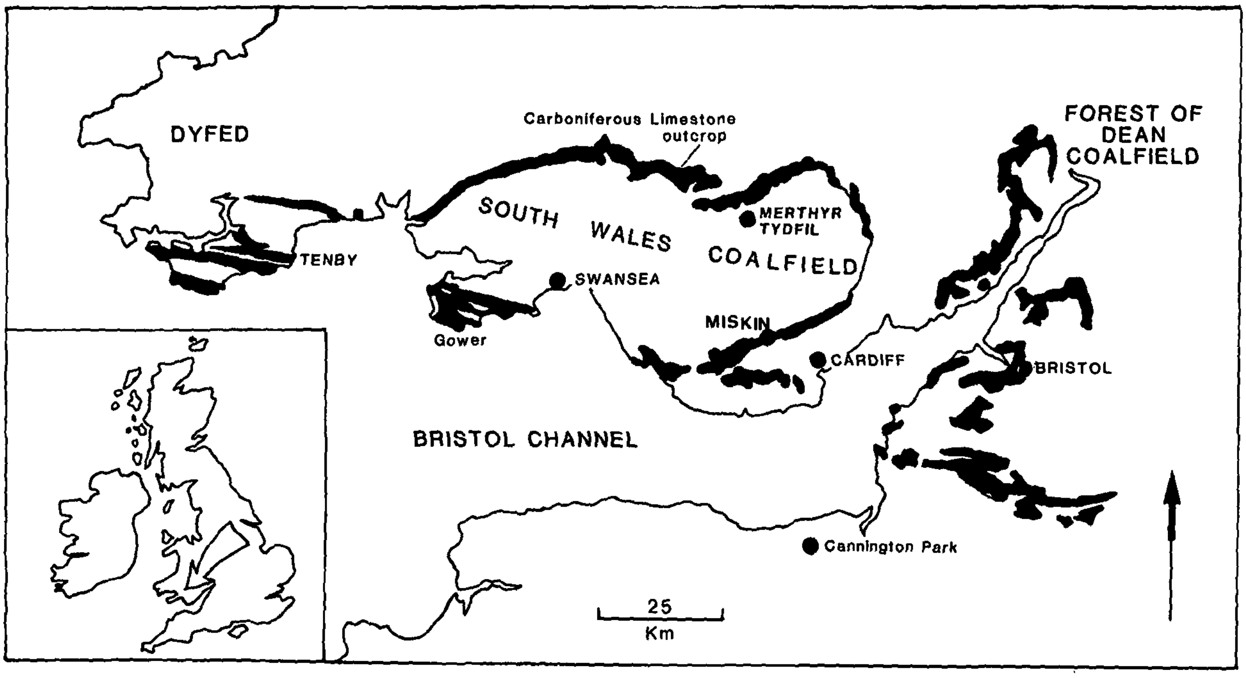
Following the initial transgression carbonate production was swamped by siliciclastic input. Such a stage is typically found following major sea-level rises and has been called a 'start-up' phase by Kendall & Schlager (1981). This phase occurs because carbonate sediments are produced *in situ* and a period of time is required before the production rate reaches its potential.

Stage II. This stage, from the late Hastarian to late Arundian, is marked by a predominance of carbonate sediments deposited as a markedly thickening wedge in which three zones can be recognized (Fig. 1). Along the northern landward edge of the limestone province, what is now the northern limb of the South Wales coalfield synclinorium, the sequence is thin, only 70 m thick, and consists of mainly oolitic and peritidal limestones with fluvial intercalations (Wright, 1986). Subaerial exposure surfaces and stratigraphic breaks are numerous and indicate periodic local uplift. Along the most southerly outcrops, in south Dyfed and the borehole at Cannington Park, the same sequence reaches over 1000 m and consists of a relatively monotonous sequence of argillaceous, locally bituminous, bioclastic mudstones to packstones with Waulsortian reef mounds (Lees, 1982; Lees & Hennebert, 1982). Intermediate between these two sequences are those exposed in the Gower and in the Vale of Glamorgan where bioclastic limestones dominate the succession but with several shallowing events represented by oolitic grainstones. The bulk of the bioclastic limestones show evidence of having been deposited well below wave base and contain storm event-beds (Wu, 1982). The oolites represent prograded oolite shoals with beach-shoreface deposits (Waters, 1984). Peritidal facies also occur but are volumetrically minor (Riding & Wright, 1981; Beus, 1984).

The predominance of shoal carbonates on the landward part of the region, and the gradual transition from shallow water facies into deeper water are both typical features of ramps (Ahr, 1973; Read, 1985) and led to the interpretation of the Hastarian–Arundian interval as a ramp deposit (Wright, 1986). Ramps are typical features of the early stages in the development of carbonate build-ups and develop soon after the drowning of continental areas (Wilson, 1975; Read, 1985).

The differential subsidence of the ramp occurred during a major phase of lithospheric extension and it may have been related to half graben or graben structures (Leeder, 1986). It is possible that the ramp itself was behaving like a hangingwall dipslope bounded to the south by the submerged Bristol Channel Landmass and to the north by structures such as the Neath Disturbance and Ritec Fault. Periodic uplift occurred along these latter structures in Carboniferous times and this activity might be analogous to footwall uplift. Alternatively the ramp may, like its classic Quaternary equivalent of the southern Arabian Gulf, have formed on the margin of a foreland basin, but it is more likely that the area developed into such a basin later in the Carboniferous.

Stage III. The Holkerian succession exhibits a very different facies pattern. The palaeogeography during much of this stage was controlled by a major build-up of oolitic and pelleted limestones in the central zone discussed above, represented by the Hunts Bay Oolite in south Wales (George *et al.* 1976; Ramsay, 1986). Behind the oolitic complex a thick series of complex, open lagoonal, oolitic and peritidal carbonates was deposited, represented by the Dowlais Limestone of South Wales and Clifton Down Limestone of Avon and Somerset (Murray & Wright, 1971; Wright,



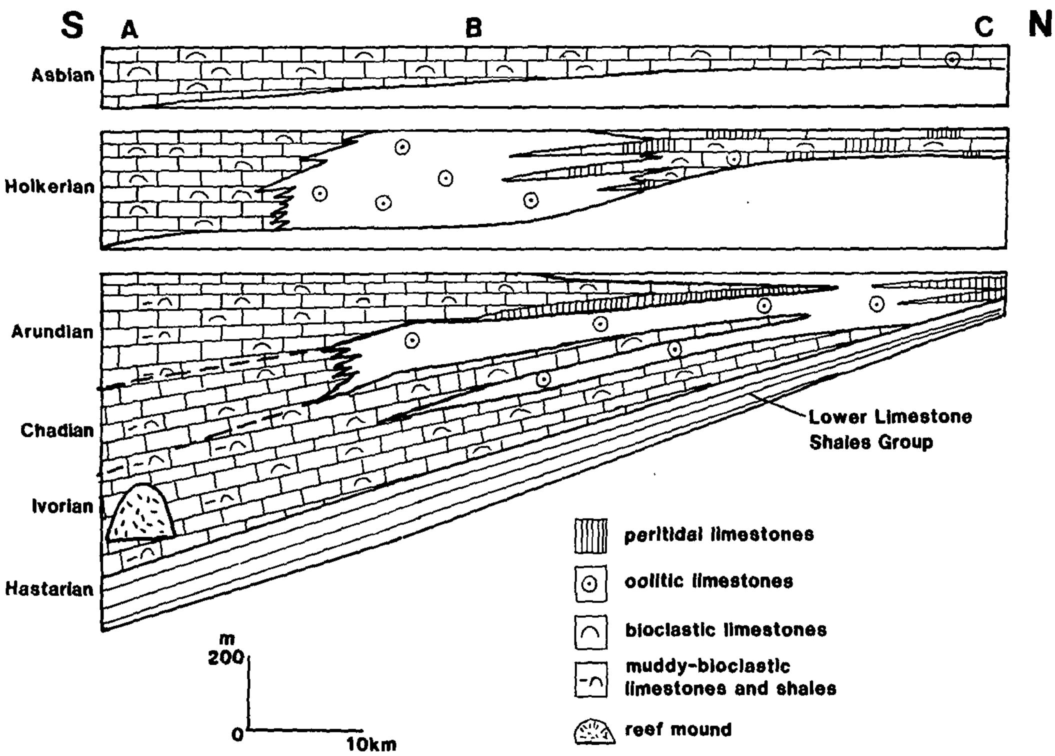


Figure 1. Carboniferous Limestone outcrop in southwest Britain and stratigraphic cross-section showing major lithofacies types (A) South Dyfed; (B) Gower and Vale of Glamorgan (west of Cardiff); (C) northern limb, northeast of Merthyr Tydfil. The Lower Limestone Shale Group (Stage I) represents a 'start-up' phase. The Ivorian to Arundian period (Stage II) represents a ramp with fringing high energy oolite shoals. The Holkerian interval (Stage III) represents a barrier-type ramp with a thick oolitic development. These two phases constitute the 'catch-up' phase of the evolution of the carbonate province. The Asbian succession (Stage IV) represents deposition on a broad 'shelf'.

1982). Seaward of the shoal complex, bioclastic limestones were deposited (Stackpole Limestone). The general configuration was of a broad, fluctuating lagoon behind an extensive, complex system of active oolite shoals and inactive, protected, stabilized pellet zones comparable to those found in major oolite shoals in the Bahamas (Tucker, 1985). This pattern can be compared to the oolitic/pellet barrier-type ramps described by Read (1985). In this model the oolitic shoals do not fringe the land mass but constitute a complex shoal-sand wave system. The Holkerian oolitic unit contrasts with those in Stage II which occur as thin shallowing-upwards units representing prograding beach-shoreface environments. The main loci of oolite formation had moved from the inner ramp area to the mid zone and such a shift may have been controlled by local tectonic changes such as a reduction in the rate of subsidence.

Stage IV. The Asbian succession is very different in style with massive to thick-bedded, fossiliferous bioclastic and peloidal limestones rich in dasycladacean algae becoming dominant over most of the region (George, 1972). The sequence contains a number of palaeokarstic surfaces (Thomas, 1953). The style of sedimentation is strikingly like the shelf limestone of north and mid Wales (Somerville, 1979; Tucker, 1985) and Derbyshire (Walkden, 1974, 1986). The facies types characteristic of the ramp stage are absent and no barrier facies or muddy storm-influenced deposits occur. The sequence can be compared to shelf cycles common in the geological record (Wilson, 1975) and each transgression and regression between subaerial surfaces is not represented by the migration of extensive ramp facies belts. While no shelf-edge can be defined, the overall style of sedimentation suggests a uniform, shallow, relatively flat, shelf-like configuration to the region.

One response to the formation of a shelf would have been the deposition of resedimented slope deposits. Such deposits do occur in the basin sequences, south of the Carboniferous Limestone province, in north Devon (Selwood & Thomas, 1986). However, these turbidites were not genetically related to the ramp-to-shelf transition or even to the earlier ramp for two main reasons. Firstly, the earliest influxes of carbonate turbidites in the basin began in Tournaisian times, much earlier than the shelf developed further north. Secondly, the turbidites contain very shallow water grains such as ooids and dasyclad fragments which were derived from shoals probably to the east and could not have been derived from the deep water facies on the southern margin of the ramp. Johnson (1984) has speculated that the present limestone province and basin configuration may be purely a function of movement along strike-slip faults.

The Lower Carboniferous limestone sequence of southwest Britain shows a four-stage development. Firstly, after the initial Carboniferous eustatic sea-level rise a siliciclastic marine system developed, representing the 'start-up' phase of carbonate deposition. During Hastarian–Arundian times a major carbonate ramp formed with fringing oolite sandbodies being developed in the higher energy inner ramp zone. During the following Holkerian time the configuration of the ramp changed and a thick oolitic sequence developed in the central part of the province, delimiting a broad lagoon in its lee. This barrier build-up represented a transition between the open ramp sequence of the Hastarian–Arundian interval and the later Asbian configuration. During this latter phase the facies sequences are different in style and resemble the shelf cycles of the Asbian succession of north and mid Wales and northern England (Walkden, 1986).

Ramp to shelf transitions have been recorded from northern England by Grayson & Oldham (1986) during Arundian to Asbian times, and during the Chadian–Arundian interval by Gawthorpe (1986). Leeder & Gawthorpe (in press) have speculated that such transitions should be a common feature of tilt block/half graben basins with the ramps developing on the hangingwall dipslope, as may have been the case in south Wales.

The controls on these changes seen in the latter three stages have yet to be ascertained but probably reflect variations in subsidence overprinted to sea-level changes.

One possible cause of the transition into a shelf may have been that the rate of sea-level rise, which had been relatively steady during the early Carboniferous, decreased sharply in early Asbian time (Ramsbottom, 1981; McCarthy & Gardiner, 1986). This pause may have allowed sedimentation to 'catch-up' with sea-level.

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